Positioning System for the LCLS Undulator

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Abstract

The Linac Coherent Light Source (LCLS) Project includes the undulator subsystem that has 33 undulator magnetic structures each 3.4 m long. Positioning of the LCLS undulators along the undulator line with an accuracy of 50 µm in the vertical transverse direction is required.

A prototype of the LCLS undulator has been built with a positioning system based on three stages with cam shafts. Each cam shaft produces reciprocating motion with a range of ±3 mm. A servomotor with integrated brake, incremental rotary encoder, servo amplifier, and controller is used with a 100:1 ratio gear box to drive each cam shaft. Resolution of the motion control is about 0.05 µm.

SmartMotors are connected in parallel through an RS-485 interface to the serial port of the computer. With this approach, the control system is easily expandable; up to 120 motors can be controlled with one serial port.

Positioning accuracy of about 10 µm for the LCLS undulator prototype is demonstrated.

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1. Introduction

The Linac Coherent Light Source (LCLS) Project includes the undulator subsystem. It consist of 33 undulators each 3.4 m long. All these undulators have to be aligned along a straight line.

Requirements for positioning accuracy are 50 µm in the vertical direction and 100 µm in the horizontal transverse direction. There is no alignment along the undulator axis. Instead, variation of the gap between magnetic structures at the undulator ends it is expected to be used to match the phase between adjacent undulators.

A beam-based alignment due to precise quadrupole motion will be used for fine tuning the electron beam trajectory.

2. Positioning System

A prototype of the LCLS undulator[1] has been built with a positioning system based on three stages with cam shafts (Fig. 1). Two stages allow two-coordinate positioning, and the third one is a one-coordinate stage. Each cam shaft produces reciprocating motion with a range of ±3 mm. A servomotor with integrated brake, incremental rotary encoder, servo-amplifier, and controller (SmartMotor from Animatics Inc.) is used with a 100:1 ratio gear box to drive each cam shaft. Resolution of the motion

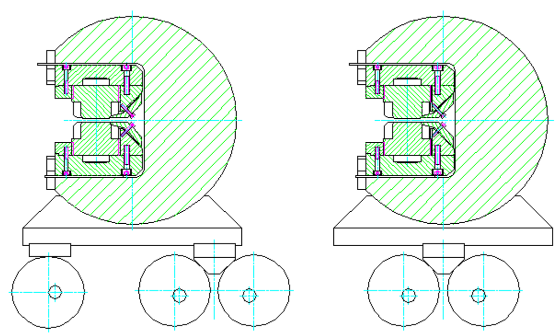

Fig. 1. Positioning stages for the LCLS undulator.

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control is about 0.05 µm.

SmartMotors are connected in parallel through an RS-485 interface to the serial port of the computer. With this approach, the control system is easily expandable; up to 120 SmartMotors can be controlled with one serial port.

3. Control System

The control program was developed using the Experimental Physics and Industrial Control System[2] (EPICS). A control screen for undulator positioning (Fig. 2) allows us to move the undulator in the X–Y directions: as a whole or at either support point, or at either end, or to rotate it around the center.

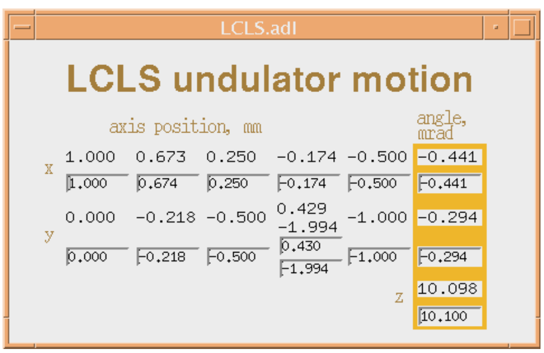

Fig. 2. LCLS undulator positioning control screen.

4. Discussion

During a test of the LCLS undulator positioning system, an incremental linear encoder was used to obtain correspondence between cam position and rotary encoder count. The cam shaft has to be rotated by at least half a turn to calibrate its angular position. Such a calibration procedure became unworkable after vacuum chamber installation through two adjacent undulators. The limited range of the vacuum chamber motion restricts us from rotating the cam shaft by a half turn. To resolve this problem, wire-wound potentiometers were installed to determine the cam shaft positions. A 10-bit ADC in the SmartMotor allowed us to easily integrate these potentiometers into the positioning control.

Positioning accuracy was tested by comparing the adjusted position with the readings of Heidenhain MT25 linear encoders with 256X interpolation. These encoders have a 0.5 µm accuracy and 10/256 µm resolution. The plot of vertical and horizontal alignment errors vs. undulator X–position (Fig. 3) shows multiple traces caused by slow self-alignment of spherical roller bearings in the positioning stages with each test pass. We plan to replace them with cylindrical roller bearings to avoid this and change the bearing outer surface from cylindical to thoroidal, which will improve positioning reproducibility to the 5 µm level. Further improvement of accuracy would require more precise gear boxes.

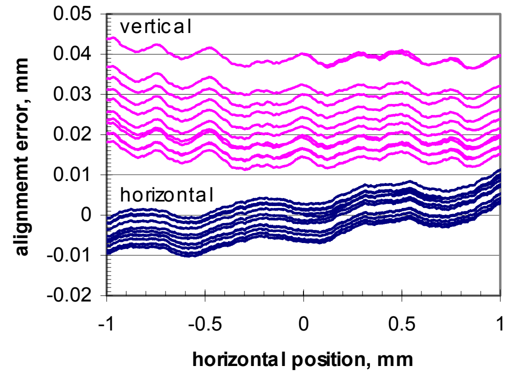

Fig. 3. Undulator vertical and horizontal alignment errors.

Some concerns exist regarding the use of SmartMotors in an environment with an ionizing radiation. We have had a positive experience using SmartMotors at the APS storage ring tunnel and LEUTL tunnel. Positioning stages can be installed with SmartMotors oriented to the downstream direction, so electronic components will be additionally shielded from ionizing radiation by the stages. Also, the positioning system is not expected to be used while operating the linear accelerator.

A positioning accuracy of about 10 µm for the LCLS undulator prototype has been demonstrated.

5. Acknowledgments

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6. References

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2 http://www.aps.anl.gov/epics/